

The new production of young scientists (PhDs): a labour market analysis in international perspective*

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Abstract

The aim of this research was twofold: firstly to highlight how the current "hybridisation" of the academic and industrial rationales exerts its influence over the new production of young scientists; secondly to compare, between five OECD countries (USA, France, Great Britain, Japan and Germany), the ways that PhDs and doctoral students are socialised within a specific -societal- set of institutional arrangements. The production of PhDs brings into play a multiplicity of institutions at various national or local levels and mobilises the various resources available to them. The interaction between them requires the agents to adopt a variety of different behaviours based on a diversity of animating principles. Thus in order to reveal the various - societal - modes of the construction of new scientific knowledge and competence, we were led to analyse simultaneously the socialisation of young scientists and the various institutional configurations. To this end, we attempted to analyse some of the essential elements that structure this process, such as the funding system, the nature of the contract between doctoral students and their supervising institutions, the rules governing the academic community, training-job transition, career paths etc.

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Introduction

In order that they can flow between the academic and industrial spaces, knowledge and competences must take on a tangible form: scientific articles, data, patents, technical objects, computer programmes, trainees, engineers, post-docs, etc. Although it is the task of the scientific community to formalise or codify knowledge, some knowledge remains tacit: a part of the new knowledge generated remains embodied in human actors in the form of competences. Since knowledge is fundamentally 'sticky' (von Hippel 1988) and tacit knowledge is context-dependent, it cannot easily be separated from the contexts or individuals that generated it. Even if we accept Callon's argument (Callon 1991) that technical objects are also actors that serve as a medium for human capacities and play a part in constructing networks, it seems to us necessary, nevertheless, to attribute a particular status to human actors such as researchers, post-docs, professors, experts and so on. These human actors are privileged tools for analysis of the structuration of the hybrid space that is emerging at the interface between academia and industry. The human actors are constructed, as occupational categories, through the interdependent relationships between, on the one hand, forms of socialisation forged within the higher education and research system (HERS) and, on the other, modes of organisational behaviour structured by firms' R&D and human resource management practices. The principles governing the functioning of institutions and of the linkage between the HERS and firms, which are often unique to a region or country, are imprinted in these human actors. At the same time, these communities of actors draw on the cognitive resources at their disposal and on the principles governing their professional *modus operandi* in order to help to specify this hybrid space and to construct specialisations in various technological fields.

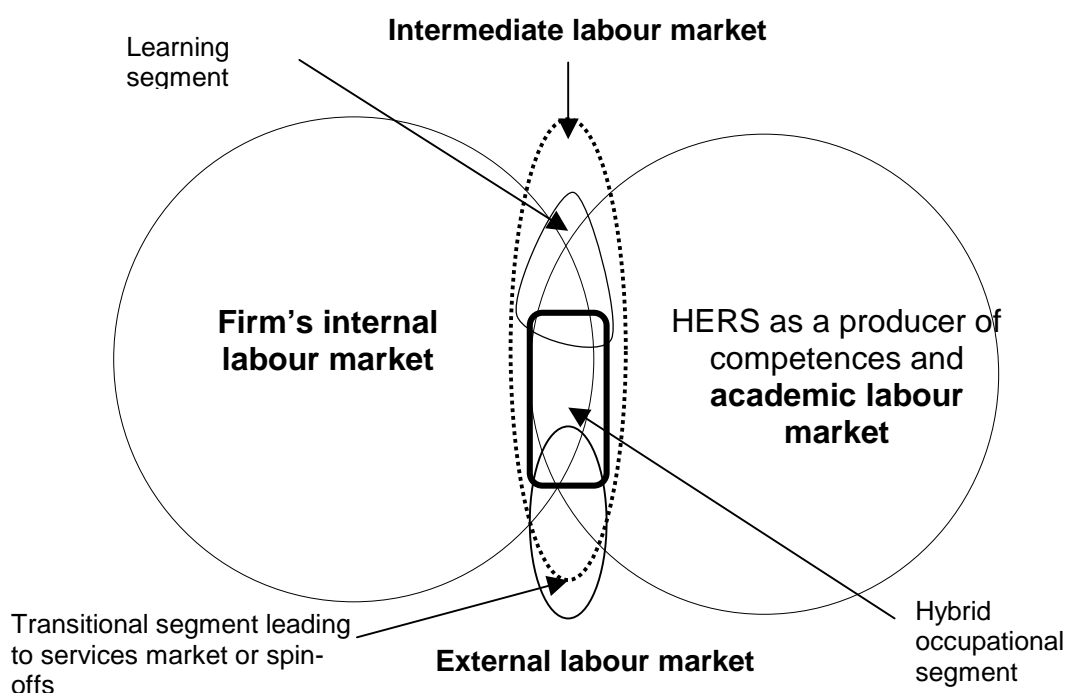
In view of the importance of human actors in the circulation of knowledge, the formation and mobility of the competences embodied in workers becomes a crucial factor in any analysis of technology transfer. For this reason, we will attempt to introduce the notion of 'intermediate labour market' with a view to capturing the new modes of coordination between universities and firms, particularly by analysing the movements of individuals (or graduates). This intermediate labour market can be seen as one of the 'bridging institutions' that function as intermediaries in the transfer of knowledge and competences between the academic and industrial spaces. It goes without saying that this mobility, embedded as it is in a set of societal contexts, has to be captured across the entire set of institutions that contribute to the production and circulation of knowledge. By adopting such an approach, we will be able to reveal societal specificities in the generation of scientific knowledge.

I The emergence of new types of coordination between science and technology

I-1 Hybridisation of the academic and industrial spaces

As technology and science converge to produce interactive innovation in accordance with the chain-linked model (Kline and Rosenberg 1986), industry and academia, represented by the scientific community within the HERS – intersect and begin to merge with each other. The scientific labour market¹, hitherto divided into the ‘republic of the scientists’ and the ‘kingdom of the technologists’, cannot remain unaffected by such a trend. Although these two spaces still have their own aims, their own principles governing the utilisation of results and their own modes of evaluation, their convergence gives rise, nevertheless, to hybrid forms of rules and coordinating practices. It seems to us that at least three new types of segments can be identified, all of them produced by the hybridisation of two spaces, which give rise in turn to new modes of functioning, new forms of mobility or new actors at the interface between academia and industry (see Figure 1).

Figure 1 - The new scientific labour market: an intermediate labour market between academia and industry



The restrictions, relative to their growing needs, on the resources available not only to universities and research organisations but to firms as well, combined with an increasingly short innovation cycle, have led to changes in their innovation strategy. They are all now seeking to establish partnerships in order to pool resources, minimise risk or increase synergy effects. Thus

¹ The notion of a labour market for scientists used in this paper is defined as ‘a labour market for individuals engaged in research activities, whether they be public or private, basic or developmental and whether the activities in question may properly be deemed to be those of a researcher or those of a scientific assistant contributing to the actual realisation of research activities’ (D’Iribarne 1987).

collaborative relations between research units and firms are proliferating and taking on forms that are increasingly contractual, long-term and productive for both parties. Such collaboration may take the form of a framework 'research agreement' laying down the conditions for a series of contracts between the two parties over a stipulated period, a research consortium, a joint laboratory or even jointly funded doctoral programmes, in which the students are jointly supervised by the firm and the research institution to which they are affiliated. These links give rise to networks through which not only knowledge but also, and above all, scientists themselves (private and public-sector researchers or research-active university teaching staff) circulate on a temporary or permanent basis (Laredo and Muster 2001). This increasingly dense two-way traffic constitutes a segment that we denote by the term 'hybrid occupational'. It is in this **first segment** that the greatest share (in both quantitative and qualitative terms) of 'hybrid' careers straddling the academic and industrial spaces is to be found.

Similarly, the formation of competences is increasingly taking place on a collaborative basis. As a result, a growing share of scientists is being jointly produced by the HERS and firms, which is creating what might be called a **learning segment**. There are two typical scenarios in this second segment. In the first, doctoral students contribute to their institution's output in exchange for grants. In view of their numbers, they constitute a pool of skilled labour that is essential to the scientific output of HERS research units. In the second, increasingly frequent scenario, students are enrolled in programmes whose content is common to firms and HERS research units; examples would include the CIFRE programme in France and the CASE scheme in the UK. Doctoral students are selected and jointly funded on the basis of criteria negotiated between the academic and industrial partners and their academic progress and/or work in industry are jointly monitored and evaluated. Increasingly, they are guaranteed subsequent employment in the organisation in which they have completed their education.

The **third segment**, which we describe as 'transitional' between the academic and industrial spaces, is characterised either by the creation of 'new services', such as consultancy services, that contribute to the innovation process and straddle the academic and commercial worlds, or by spin-offs set up by researchers or universities. Post-doc contracts proliferate in this segment. Located half-way between 'training' and precarious scientific employment, such contracts give firms access to a highly skilled workforce, a veritable repository of new knowledge and know-how, without them having to commit themselves to a period of employment greater than one and half years. They also enable research institutes to employ new PhDs to work on projects while they wait for a permanent position or to implement technology transfer projects aimed at industry. Sometimes, the same individual may hold a succession of post-doc positions, particularly in high-tech areas such as the biotechnologies. Nevertheless, this holding of a succession of post-doc positions, which is caused by the 'queuing' phenomenon, often makes it more difficult for the individuals concerned to obtain a permanent academic position (Mangematin and Mandran 1999).

Thus the scientific labour market is evolving from a form in which there was a clear distinction between academic and industrial careers towards increasingly less 'pure' and increasingly more 'mixed' or 'hybrid' forms.

I-2 The emergence of the 'intermediate labour market'

The existence of these various, mutually interacting segments is leading to the construction of a new type of labour market in which the networks through which scientists circulate and new career paths, such as those offered by academic spin-offs for example, are disrupting the previously well-established mobility system. We use the term 'intermediate labour market' to denote this new market because it is the product of different dynamics jostling up against each other in a new hybrid space and because at its core lies the threefold relationship between industrial, academic and public actors that is familiar from 'triple helix' theory (Ezkovitz, Leydesdorf 2000).

In our definition, the intermediate labour market denotes a set of coordinating mechanisms by means of which two (or more) partners are able to procure the human resources, competences or expertise required to generate new ideas or realise innovations. This notion goes beyond the general definition of the labour market as a system for allocating the production factor labour through price mechanisms. It is a notion in which the principles governing markets and those governing organisations interpenetrate, reflecting a process of hybridisation between what economists customarily describe as the 'external market', in which adjustments are effected through both the price mechanism and the free movement of individuals, and the 'internal market', whose rules (embodied in incentive systems) guide the construction of career paths over time. This hybrid space is essentially structured around the use of mobility networks, which give tangible form to the compromises that emerge from 'bilateral governance'² - in the sense of the term ascribed to it by Williamson (1985). Within this space, and despite differences arising out of frequently contradictory institutional objectives, the strategies of universities and those of firms, together with the individual choices made by students and researchers, come up against each other in order to determine common interests.

In our view, the academic value of introducing the notion of 'intermediate labour market' into our analysis is threefold.

Firstly, it allows us to focus not on the exchange of already formatted or certificated competences but on the **co-production of resources or competences**, which is playing an increasingly central role in the non-linear model of innovation. The notion of the intermediate labour market takes us beyond the rules governing market transactions in order to describe the institutional arrangements that enable resources to be shared and knowledge

² We are in fact dealing here with 'trilateral governance' if we include the state as an actor intervening in science or higher education policy. This last actor, whose activity varies in intensity from country to country, has the capacity to structure the intermediate labour market by various means, including grants, research funding, management of university posts and so on.

and competences to be jointly produced at the interface between academia and industry.

Secondly, it enables us to take account of the fragmentations of this intermediate space that necessarily arise out of the tensions between the principles animating the academic and industrial spaces, which are sometimes complementary and sometimes contradictory. Since the compromises between the two worlds are always fragile, there is a need for flexibility that leaves its mark on the intermediate space. The fragmentations frequently manifest themselves as pairs of opposing characteristics, such as precarious/stable, statutory/non-statutory, education-training/work, wage work/non-wage work and so on. The intermediate labour market can impart an overarching meaning not only to a particular configuration of the various segments but also, and above all, to their permanent reconfiguration, since the boundaries of each segment remain porous, permeable and shifting.

Finally, it enables us to incorporate into our analysis the temporal aspect of the overall dynamic. The adjective 'intermediate' denotes the positioning not only at the interface of two spaces (the mediating function) but also between two states in the evolution of organisational forms. For example, a spin-off from academia evolves over time, moving, if it is successful, from the status of publicly-funded researcher/project group to a standard corporate form, via an intermediate status such as 'company founder nurtured in academia', 'new start-up consisting of a founding team', 'unincorporated' company and so on. As that example clearly demonstrates, the notion of the intermediate labour market is a tool for analysing a temporary state that exists prior to the solidification of an organisational form. In this sense, our approach is closer to that adopted by Callon (1995), which involves studying '*knowledge in the process of being created*' (competences in our case) by making a distinction between the 'cold' world of economists, that is the market, and the 'hot' world of sociologists, that is the space in which the creative activity takes place.

II The labour market for PhDs in international perspective

Drawing on the results of the SESI European research project³, we will make an initial attempt to compare the conditions under which science PhDs are produced and integrated into the labour market in five countries (USA, France, Great Britain, Japan and Germany)⁴.

It is true that this category of actors is only one of the elements around which the intermediate labour market is structured. However, quite apart from the fact that they account for the highest share of the annual flows of scientists and therefore of the circulation of knowledge, their training and integration into the labour market brings into play a whole set of public and private institutions in the sphere of science and innovation (Buechtemann and Verdier 1998).

³ Our investigation is based on the empirical results of a comparative study, funded by the European Commission during 1998-2001, of the relations between firms' innovation systems and higher education and research systems (SESI) in Five European countries and USA. See in detail, <http://www.univ-aix.fr/lest/sesiweb/>

⁴ From a different point of view, Barton Clark had made a significant study on the research training system at the graduate school level with the same five countries (Clark 1993).

Thus our aim here is to highlight a certain type of socialisation the actors undergo in a given sectoral and/or national context by using the mode of production and deployment of PhDs in science and engineering as our analytical tool. In other words, although the hybridisation of the academic and industrial spaces is taking place everywhere, it takes different forms depending on the characteristics of the sectoral and/or national space whose pre-existing institutional arrangements exert a strong influence over the actors, in this case PhDs and doctoral students, being socialised within it. In this sense, our analysis falls completely within the framework of the institutionalist theoretical school known as the **national system of innovation schools** (Nelson 1992, Lundvall 1992,1997, Edquist 1997). However, drawing on the lessons to be derived from **societal analysis** (Maurice, Sellier, Silvestre 1986), we stress the importance of incorporating into the institutional analysis the **notion of actors** who, despite being socialised by the system, are also capable, as they go through their own learning processes, of acting on it and amending or modifying it.

We will begin by presenting some quantitative data on the production of PhDs. We will then return to a more qualitative analysis, focusing on some of the aspects that structure the process whereby PhDs are socialised.

II-1 Annual flows of PhDs in natural sciences and engineering

We will briefly examine the state of the production of new PhDs in the five countries. Table 1 summarises the flows of PhDs in 1997 and their evolution between the end of the 1980s and 1997 in all five countries.

Tableau II Doctoral degrees in natural sciences and engineering 1997

	UK	Germany	France	Japan	USA
A) labour force (1000 persons)	28552	39455	26404	67110	133943
B)PhD S and E	6315 (100)	9499 (100)	7333 (100)	5769 (100)	19309 (100)
Of which PhD sciences	3589 (57)	5964 (63)	4494 (61)	1315 (23)	10290 (53)
Of which PhD Engineering	2726 (43)	3535 (37)	2939 (39)	4454 (77)	9019 (47)
A/B (ratio .000)	0,22	0,24	0,28	0,09	0,14
Ratio progression (1989/1997)	of 1,28	1,08	1,74	1,70	1,28
		(1990/1997)			

Source; calculated from NSF science & Engineering indicators1999

Of the countries under consideration, the three European countries are, in relative terms, the largest producers of PhDs. France heads the league table, in terms of density, with 7,300 new PhDs per year, closely followed by Germany (9,500) and the UK (6,300). The USA is in a paradoxical situation: throughout the 1990s, it was the unchallenged leader in scientific output and technological innovation and yet the standard human capital indicators (R&D density in terms of personnel or PhDs) for that period seem to be relatively mediocre. Nevertheless, in absolute terms, those indicators do record massive inflows into the scientific labour market of 19,000 new PhDs. It

should be noted, nevertheless, that in the United States one third of doctorates in natural sciences and more than 40% in engineering are submitted by foreign students, which shows that the international reputation of American research universities exerts considerable power abroad. If these foreign students are excluded, the ratio of PhDs to the economically active population of the US drops to the level found in Japan, which lags a very long way behind the others in this respect. Moreover, like the United States, Japan has a very pronounced bias towards engineering PhDs, to the detriment of those in basic science. The European countries, in contrast, particularly France and Germany, where the public research institutions have a not insignificant influence, produce more doctorates in natural sciences.

Examination of the evolution over the 1990s reveals two trends. The first is the increasing level of the highest degree obtained by university graduates in the various scientific and technological disciplines, and in particular the rise in the number of PhDs. Thus the production of PhDs has risen in absolute terms in all the countries. However, the rate of increase varies from country to country: virtual stagnation in Germany, moderate growth in the USA and the UK and sustained growth in France and Japan. The second is the more or less pronounced slowdown (except in Japan) in the flows of new entrants into science and engineering faculties, despite the general trend towards widening access to higher education. Thus as early as the mid-1990s, Germany and the USA were already experiencing a slight decline in the flows of new doctoral students. France and the UK have experienced the same phenomenon more recently, which does not bode well for the number of PhDs produced in future. Germany is a particularly interesting case, since the country has already seen a drop in the absolute numbers of students enrolled in departments of electrical engineering, chemistry, biology, pharmacy etc. This phenomenon, which can also be observed to varying extents in France and the UK, seems to be linked to two factors. The first is the economic boom of the late 1990s based on the new technologies, which absorbed many post-graduate students, and the other is the declining attractiveness of academic careers because of the saturation of the academic labour market.

II-2 Analysis of the national modes of production and deployment of PhDs

From our analytical perspective, the function of PhDs – and of doctoral students – is threefold: they are the resources used to produce the scientific output of the teams within which they operate, the pool from which the next generation of scientists will be drawn and the primary vector for the transfer of knowledge between academia and industry⁵. As a collective entity, they

⁵ The doctorate study implies a multifunctional mechanism and corresponds, in a traditional sense, to the 'apprenticeship system'. The students are, first of all, to acquire knowledge of the latest scientific advances. In return, they contribute to the collective scientific output by specialising in a specific area within their team. Secondly, it serves to produce the next generation of lecturers and researchers whose task it will be to provide leadership in the scientific research of the future; this equates of course to the reproduction of the academic community. Finally, the flows of doctoral students and PhDs between the HERS and firms are

implement these three different functions, although individually they are often devoted to one function, according to their strategic choice. This category of young scientists as a whole is thus produced by and constitutes an institutional nexus which emerges at the frontiers between academia, industry and public authorities. They reveal the quality of the intermediate space and at the same time contribute to forge this space.

The production of PhDs brings into play a multiplicity of institutions at various national or local levels and mobilises the various resources available to them. The interaction between them requires the actors involved to adopt a variety of different behaviours based on a diversity of animating principles. Thus in order to reveal the various societal modes of the construction of new scientific knowledge and competences, we need simultaneously to analyse the socialisation of the actors and the various institutional configurations. To this end, we will continue by analysing some of the essential elements that structure this process, such as the funding system, the nature of the contract between doctoral students and their supervising institutions (Implicit contract, according to Stephan 1996), the rules governing the academic community, training-job transition, career paths etc (See the recap figure in annex).

II-2.1 The funding of doctoral programmes

The United States has the most highly systematised PhD programmes, although they are decentralised and differ from university to university. The power of the graduate schools run by the research universities, which are characterised by their autonomy, the competitive environment in which they operate and, above all, their concentration (there are about 50 research universities of international standing), gives this model the status of an international reference point in this regard. The American system produces slightly fewer than 20,000 new PhDs in science and engineering each year. Its scale makes it possible to rationalise academic programmes and to manage research funds, to tap the various sources of funding and to create the conditions for the efficient production of scientific output and PhDs based on economies of scale. As far as funding is concerned, many students receive assistance from research funds gathered outside the university system but managed directly by the universities (and the individual research teams). These funds are used to establish assistant teaching or research posts. On the other hand, relatively little use is made of national or federal core funding. In other words, the quality – and the reputation – of individual research teams and universities depends to a large extent on their ability to tap the various sources of funding (federal, military and private) that make it possible to put the ‘best’ doctoral students to work on promising topics. Thus reputation plays an essential part in effecting the match between financial resources and ‘talent’.

Japan is one of the countries that produces the fewest scientific doctorates per year, whether measured in absolute or relative terms. This reflects the low

the means by which the new knowledge produced in academic research institutes is diffused beyond the boundaries of academia.

status of basic science in that country and the low level of state investment in it. Weighed down by their oligarchic mode of governance based on the 'chair' system, which gives professors very considerable independence, the universities have lacked the flexibility to set about transforming their doctoral programmes. Since the late 1990s, the state has been trying, nevertheless, to establish so-called 'daigakuin daikagu', modelled on the American graduate schools, with a view to increasing the number of PhDs produced and creating 10,000 post-doctoral positions in order to expand job opportunities within the university system. With a few rare exception, however, the major source of funding for doctoral students remains interest-free loans.

In Europe, doctoral programmes are much less systematised than in the United States and still reflect the various national institutional heritages (Clark, 1995). Nevertheless, the three European countries under consideration here did initiate reforms during the 1990s, albeit in their own different ways.

The system in **France** is characterised by the fragmentation of university research teams and the dichotomy between the universities, on the one hand, and the elite *grandes écoles*, on the other. In recent years, however, doctoral programmes have been reformed in order rapidly to increase the number of PhDs produced. The universities have tended to set up research schools in order to take advantage of economies of scale. The *grandes écoles* have also expanded the part they play in the production of PhDs by strengthening their 'engineer-PhD' programmes. Funding for doctoral students is based to a large extent on the various grants awarded by government ministries, and in particular MENRT (Ministère de l'Education Nationale et de la Recherche, or Ministry of National Education and Research). Thus 85 to 95% of doctoral students in science and engineering, depending on the discipline, are funded by one or other of these grant-awarding bodies (MENRT 2000). The distribution of these grants among the various research units seems to remain relatively stable, at least in the medium term. Similarly, the grants awarded by organisations such as the DGA (General-Directorate for Armaments), the CEA (Nuclear Energy Centre), the CES (Space Studies Centre), France Télécom and so on go mainly to a certain number of laboratories with whom they have established good working relations. In contrast to the USA, the funding of doctoral students is relatively unconnected to direct academic competition; the system of grant allocation tends rather to be administrative in nature (MENRT-type awards) or to be based on long-term partnerships.

Although the Humboldt model, in which teaching and research is seen as an indivisible whole, has been the basis for the effectiveness of **German universities**, little distinction is made between doctoral research and other advanced training programmes and the production of PhDs is relatively unsystematised. In other words, the selection process, courses and pedagogic content are not highly structured, as they are in the American system. In consequence, the career paths for students embarking on a doctorate are not very well signposted, particularly since the length of time they take to complete their theses remains highly variable. In this respect, the reform of doctoral training is however under way.

Three quarters of doctoral students are employed as junior staff in universities, although their conditions of employment (full-time/part-time, length of contract and so on) seem to differ considerably from one field to the next. These posts are funded partly from local (Land) and national (federal) government grants provided for in annual budgets and partly from the public or private research funds that selectively finance projects on which doctoral students can apply for assistantships. Particularly in this latter case, they are dependent on the reputation of the professor/PhD supervisor, who often manages scientific projects involving both the university and research institutes, on the one hand, and the university and industry, on the other. As a result, many doctoral students are from the outset members of research teams in which their personal work forms part of the team's collective programme.

In the **United Kingdom**, as in Germany, PhD students can take a number of different routes. Entry conditions for those who have completed the 3-year undergraduate degree, the length of time taken and the way in which the doctorate is obtained differ from discipline to discipline, even though efforts are being made to formalise programmes and the final assessment. As far as funding is concerned, the research councils distribute the major share of grants on the basis of individual academic merit, with other public organisations, notably the universities themselves, accounting for most of the remainder. Thus 75% of full-time PhD students have their tuition fees⁶ paid by public bodies. Half of them receive money from the research councils and a quarter from the universities, government ministries or local authorities; firms seem to make only a very limited financial contribution to the production of PhDs (funding a mere 337 students out of a total of 5180) (SET Statistics 2000). On the other hand, more than half of all part-time doctoral students are self-funding because of their restricted access to government grants (23%) or funding from business and industry (15%). However, the general trend in the funding of doctoral students is towards a gradual withdrawal by the state, which is forcing the universities and the research councils to diversify their sources of finance. An increasingly large share of doctoral students is being co-funded by industry and the universities within the framework of programmes such as CASE⁷ and PTP.

II-2.2 Characteristics of the Doctoral students; reflect of institutional forms of University system

Doctoral students in the **United States** constitute a very heterogeneous population, reflecting the great diversity within the university system itself. The freedom each university has to fix its own rules or procedures for awarding PhDs, combined with the relatively large numbers of students who interrupt

⁶ In most cases, the grant covers both tuition fees and student's living expenses for 3 years.

⁷ Like the CIFRE programme in France, the aim of the CASE scheme is to place PhD students whose work will be supervised jointly by academia and industry. This programme is largely funded by the research councils. CASE funding was originally restricted to the universities, but in 1994 the rules were modified to include business and industry. As a result, the research councils can now award grants directly to selected firms on the basis of PhD proposals submitted (Office of Science and Technology 1997).

and then return to their studies, means that the socio-demographic characteristics of doctoral students are fairly disparate. The absence of any centralised (federal) certification for doctoral programmes also has the effect of making the quality of the degrees awarded less than transparent. Furthermore, the number of foreign doctoral students and post-docs, which varies from discipline to discipline (34% in natural sciences, 49% in engineering, according to the NSF), is still very high, as we have already seen. The large numbers of foreign students is proof of the attraction exerted by certain American research universities; at the same time, they constitute a pool of skilled labour on which the scientific labour market, particularly that for post-docs, can draw.

For slightly different reasons, the **United Kingdom** also has fairly diversified populations of doctoral students. Since specialisation begins at a very early stage here, from the age of 16 onwards, and the total time spent in higher education can be relatively short (6 years may be sufficient to reach PhD level), some students obtain their doctorates at a young age, around 25. On the other hand, a significant share of doctoral students, working part-time for their PhDs, take a very different path through the education system, in terms both of time spent in the system and scientific background or motivation. In the 1995 academic year, there were 5180 new entrants on to full-time doctoral programmes in science and engineering, compared with 1883 students registering to study part-time; thus a quarter of new entrants in that year were part-timers. This category of students, many of whom have previously worked or are continuing to work while studying, accounts for a not insignificant of the total doctoral student population in the United Kingdom. Moreover, as in the USA, foreign students account for a significant share of the new doctorates awarded (30-50%). This diversity, combined with that of the universities themselves, makes quality standards a little difficult to assess.

On the other hand, the PhD populations in the other three countries are relatively homogeneous, although this homogeneity is not of the same kind. In **Germany**, many students embark on a higher education course in a technical or scientific subject on completion of an apprenticeship begun after obtaining the Abitur at age 19⁸. Even though they may subsequently leave higher education at various levels, the professional experience acquired during the 2 to 3-year apprenticeship serves as a sort of common basis for creating a professional identity that facilitates cooperation among technicians, engineers and researches. Graduates tend to obtain their degrees late because of the relatively long time taken to complete the bachelor's and master's programmes, which have no real cut-off point. For example, the average age at which a university student becomes a graduate engineer is 29, and 31 for students in the *Fachhochschulen*. Consequently, those who prolong their studies beyond the graduate engineer level in order to obtain a PhD are delaying still further their entry into the labour market. Doctoral students tend to complete their doctorates between the age of 31 and 35, which seems late compared with the French average of 29. Even though the funding

⁸ This applies to 82% of new students entering the *Fachhochschulen* (polytechnics) and to 55% in the universities.

arrangements mean that their academic careers are slightly different, the PhD population retains certain homogeneity, which is further reinforced by the fact that Germany attracts significantly fewer foreign students (8%).

France and **Japan**, on the other hand, are characterised by the relative coherence of their doctoral student populations: virtually all PhD students in these countries study full-time, apart from those Japanese employees who submit theses based on their work and some of the foreign students in France. In both these countries, students' progression through the system follows a relatively linear path from high-school graduation to PhD. The procedure for completing theses is standardised and takes a relatively short time, with students often completing before age 30. This normative procedure creates a certain coherence among each cohort of doctoral students, although in France of course there is the duality between universities and *grandes écoles*, while in Japan the university hierarchy tends to divide the PhD student population. Foreign students account for around 20% of doctoral students in both countries.

II-2.3 The training-career transition in academia

Obtaining a PhD has traditionally been regarded as preparation for an academic career, either in universities or in publicly funded research institutions, where the careers of teaching and research staff are governed by strict rules: recruitment based on academic publications record, peer evaluation, tenure or employment guarantees and so on. The tenure system often emerges as a major issue in academic careers, particularly in the English-speaking world, since it serves both as an incentive mechanism for those starting their careers and as the boundary marker beyond which job stability in the internal market allows academics to specialise and extend their knowledge without the threat of academic obsolescence or dismissal. This canonic model of the academic labour market seems to be largely a fiction, however, if only because, in reality, it functions very differently in different societal contexts⁹. In order fully to understand its diversity, we will need to consider two mechanisms: the first concerns the internal workings of universities, while the second relates to the nature of the implicit contract between doctoral students and their supervisors, who fix the rules governing the balance to be struck between students' contribution to collective research and the development of individual careers. The first influences the rules or practices governing recruitment, while the second tends to shape the strategies PhD students adopt in respect of their own career aims.

a) In the **United States**, the academic labour market is characterised, firstly, by extensive segmentation between two types of university, teaching universities and research universities (public research institutions), with teaching and research staff being managed in accordance with the different

⁹ Moreover, as we will see later, academia does not have a monopoly in the PhD market, since industry absorbs a significant share of PhDs, albeit one that varies from country to country.

missions of the two types of institution¹⁰. It is characterised, secondly, by the tenure system, which offers young academics an incentive to produce knowledge, particularly in the second category of university, among which there is intense competition. This dual competition at the individual and collective (inter-establishment) level is based on the '(academic) reputation system' which functions as a sort of stock market quotation in a quasi-commercial marketplace and is the basis for the hierarchy that characterises the American university system. Unlike in France or Germany, *'where the discourse is egalitarian and where the universities are all supposed to be of comparable quality and to award degrees of the same value'* (Brisset-Sillon 1997), universities in the USA are systematically ranked, which has the effect of hierarchising and segmenting the academic labour market. The main differentiating factor in this hierarchy is research: the best institutions are those that have a high level of academic/scientific output and manage both to tap the available financial resources to the fullest extent possible and to attract the best talents. The careers of teaching and research staff tend to espouse the same principle of competition based on reputation.

In accordance with this same principle, the contract between doctoral students and their supervisors seems to be based on a reciprocal commitment to a relatively explicit form of exchange. PhD students undertake, while working on their theses, to contribute to the production of new knowledge within the group research directed by their supervisors or professors, while the latter agree to provide them with an academic environment as conducive as possible to the production of interesting findings and, above all, of articles for publication in the leading academic journals, which in turn guarantees their academic future. However, this mutual commitment is limited in both time and space, since a PhD thesis is only one staging post on the route to academia, access to which remains highly uncertain. The allocation of research funds, including assistantships, is extremely competitive, the process of obtaining tenure is both lengthy and selective and mobility between projects or research teams is the rule. It is important for young academics, therefore, to adopt a strategic approach to constructing their academic reputation by accumulating positive signals as they work with various research teams, collaborate with various professors and help to run a variety of different projects. Each commitment to these various contracts is intended to create a positive dynamic.

Currently, slightly fewer than two thirds of PhDs are employed in university or academic positions three years after obtaining their doctorates, while only one quarter are employed in firms (NSF 1998). Thus PhD students in the USA are being prepared mainly for careers in the 'academic space', and particularly in the university system. Nevertheless, the vast majority of new PhDs find themselves accepting temporary posts and thereby joining the queue for tenured or tenure-track positions. This selectivity, which has become more intense in recent years, makes the situation of young academic precarious to

¹⁰ This is a very simplified typology of the 3,600 such institutions in the USA, which can be further distinguished by their nature (public or private), by the length and level of courses offered and by reputation. The classification drawn up by the Carnegie Foundation in fact has 10 categories.

some extent, which reduces the attractiveness of academic careers and tends to restrict enrolment on PhD programmes, at least in some subject areas.

b) The situation in the **United Kingdom** is not dissimilar to that in the USA. Here, the higher education system comprises a total of 113 university institutions and has been unified since 1992. Nevertheless, these institutions can be divided into two distinct categories, the 'old' or pre-1992 universities, and the 'new' or post-1992 universities, which grew out of the former polytechnics. Universities in the first category, which forms the basis of the British system, provide courses at all levels, with teaching and research being closely linked. It includes the ancient universities as well as technological universities and the so-called 'redbricks', founded in major cities such as Manchester and Leeds in the late 19th and early 20th centuries. The post-1992 universities concentrate more on undergraduate teaching. They have a significant number of part-time students and students on sandwich courses. Although current policy in Britain is aimed at creating a homogeneous system by increasing the number of crossover points between the two categories, the academic labour market is highly segmented between the new universities, which concentrate mainly on teaching, and the traditional universities, in which most research is conducted. Although they are less autonomous than American universities, the most prestigious British universities enjoy a not-insignificant degree of freedom, far more in any event than their French and German counterparts, in matters of recruitment, promotion and incentives for teaching staff. The allocation of public research funds on the basis of the Research Assessment Exercise increases competition between universities, which in turn influences academics' career paths, as it does in the USA. Furthermore, although the tenure system was formally abolished in the late 1980s, the goal of most young academics is to obtain a permanent lectureship, which offers far greater job security than that enjoyed by contract research staff, the vast majority of whom are employed on fixed-term contracts. The contract researcher category, which accounts for almost 30% of faculty staff and provides support for university research activities, acts as a sort of 'airlock' in which young academics destined for lectureships are sorted out from the rest, who are likely to seek work in the private sector.

The implicit contract between doctoral students and their supervisors, which is based on a mutual commitment, is intended here, as elsewhere, to ensure that the work students do for their theses also adds to the research teams' output and reputation, with benefits for both parties. Doctoral students appear to enjoy greater room for manoeuvre here in constructing their individual strategies, since most of them receive grants to support their studies. In this sense, British PhD students are able to adjust their level of involvement in their teams' research in accordance with the likelihood of their obtaining a position in the academic community. Nevertheless, those seeking such a position have to go through a lengthy selection process which forces them to take part in a sort of protracted knock-out tournament. By way of illustration, a survey carried out by the Wellcome Trust, a private research foundation, shows that, after completing their theses, 80% of young PhDs in the biological sciences find their first jobs on fixed-term contracts in academia; however,

only 60% remain after three years and this figure falls further to 47% beyond the four-year mark.

In the other two European countries, the higher education system is managed by centralised supervisory bodies whose management procedures are more or less bureaucratic. The market mode of coordination based on reputation or 'share price' is replaced here by an administrative mode. While it is true that certain establishments are more 'recognised' than others, the inter-institutional competition and hierarchies are not as explicit or as transparent as in the USA or the UK¹¹. Thus the doctorates awarded in these countries, regulated and controlled as they are, reflect a certain quality standard.

c) In **Germany**, the academic labour market is organised by the supervisory authorities, which operate on two different levels: *'the federal government lays down a general framework of rules and procedures governing the university system, a framework within which the individual Länder or states are able to develop a certain number of options. The Länder are also very active in negotiating professors' salaries, since they are requested by the universities to find the necessary funds'* (Musselin 1994). Although university teaching staff in Germany are civil servants, as they are in France, they do not generally obtain a permanent position until the age of about 40, when they are appointed to a professorship following completion of their *Habilitation*, a second doctorate that confers entitlement to teach in a university. Moreover, the system attaches a certain number of supplementary conditions to the recruitment procedure: candidates already in post cannot be promoted unless they change institution; once selected, they may negotiate additional payments and working conditions with the university, in particular research budgets (including assistantships). Compared with the conditions in the French market, young assistant staff have to be mobile in order to obtain a permanent position and also have to go through a lengthy apprenticeship and selection process under a professor's authority that lasts until the age of about 40. The status of professor is the central pivot around which the German university and research systems are organised. Indeed, unlike in France, where university staff and public-sector researchers have separate career paths, it is the university career path leading to the status of professor that is the obligatory route for all academics and allows them subsequently to be considered for positions of responsibility in extra-university research institutions funded by the state or by industry, such as the Max-Planck Institute, the Helmholtz Centres, the Fraunhofer Gesellschaft etc. It is through these public or semi-public research organisations that German industry receives a steady flow of professors, doctoral students and post-docs as part of a process of cross-fertilisation that reflects the close cooperation between science and industry.

In view of the importance of the status of professor, the implicit contract is based more on the individual relations between professors and PhD students, or even on a master/pupil relationship along the lines of the classic Humboldt model in which they come together around a common research object. This

¹¹ Except of course for the distinction between universities and *grandes écoles* in France.

type of personalised relationship, based less on the value of the student's immediate performance, tends to restrict the scope for young academics to adopt individual strategies. As a result, they seem to be more dependent on the relational networks established by their professors in order to gain a foothold on the various professional career paths. This is particularly true of those who embark on academic careers.

d) In **France**, the higher education and research system is an archetypal example of a system controlled by the central state, even though the state is currently seeking to reduce its financial commitment and to give establishments greater autonomy under local management. It is further characterised, over and above the university/*grande école* duality¹², by a clear distinction between the universities and public research establishments, which each have their own separate missions, namely teaching and research respectively. This distinction has served to create two separate professions, researchers and lecturers. Thus the academic labour market is divided into separate segments between which there is little mobility. Nevertheless, the same rules govern the service of all academics, whether teaching staff or full-time researchers, since virtually all of them are civil servants. In France, therefore, the rules governing the service of university staff and researchers are laid down by the state. The distribution of posts is managed by the central administration within each system. The management of individuals – recruitment and promotion – is the responsibility of the relevant corporate body. University teaching staff and researchers become civil servants on obtaining their first permanent lecturing position (*maître de conférence*) or research post (*chargé de recherché*). Having gained tenure around the age of thirty, university teaching staff and researchers enjoy job security, behave as 'insiders' in the internal market and display a propensity to shut themselves off from its economic environments.

As far as the nature of the contract governing relations between doctoral students and their supervisors is concerned, there is a not insignificant element of personal commitment, as in Germany. In France, however, these relations are shaped more by the institutional aspect of the contract that links PhD students to their laboratories or research units. Indeed, since the conditions under which they complete their theses, particularly the allocation of grants or the industrial contracts under which support is provided, depend to a very large extent on the laboratory to which they are affiliated, they feel themselves more involved in the workings of their institutions. This tendency is further reinforced by the fact that the competitive procedures by which young academics are recruited to teaching or research posts frequently go beyond the selection of individuals to become competitions between individual laboratories. Individual strategies certainly exist, but they have to be implemented, in the form of co-option, within a space shaped by the constraints imposed by wider institutional strategies.

¹² The French case is somewhat exceptional, since universities in France are not the centres of excellence that they are in other countries. They are regarded as the 'second choice' relative to the elitist *grandes écoles* and also as less productive in terms of research output than the public research institutions.

e) In **Japan**, the academic labour market is characterised by the coexistence of the private sector (private universities) and the public sector (national universities and public research bodies). In this latter sector, young academics gain tenure at a relatively early age, as in France. Even though each institution has the freedom to determine its own procedures and criteria for selection and promotion, they are all governed by the national scales. This system has the effect of rigidifying the management of teaching and research careers by destroying incentive mechanisms. A recent reform created 10,000 fixed-term post-doc positions funded entirely by the state with the aim of introducing greater flexibility into the organisation of public or university-based research. Private universities enjoy greater room for manoeuvre in career management, at least in theory, although in fact the employment system closely resembles that in the public sector. This rigidity in the academic labour market is further reinforced by the 'chair' system which, as in Germany, tends to freeze the boundaries between disciplines or sub-disciplines. Moreover, it gives every professor, whether in the public or private sector, considerable freedom when it comes to the choice of courses, programmes and appointments. The importance accorded to the status of professor places doctoral students and young PhDs in a position of both academic and professional allegiance, which creates a sort of master-pupil relationship. The implicit contract is replaced by this type of highly personalised relationship, which reflects a wider system of mutual expectations.

II-2.4 The recruitment of PhDs in the private sector

Labour market transactions are characterised by uncertainty caused by informational asymmetries. One of the ways in which this uncertainty can be reduced is to evaluate individuals and their competences on the basis of the signals they transmit in the form of qualifications, experience, areas of specialisation, research topics, institutional affiliation, etc. These signals include, on the one hand, more or less objectified elements, such as degrees and publications record, which constitute a form of certification of competence and quality and, on the other, subjective elements, interpreted by the actors, which provide the basis for reputations. Thus 'certification' and 'reputation' are two major modes of coordination around which the encounter between supply and demand in the labour market is organised. Nevertheless, these modes of coordination become increasingly less satisfactory as subject corpora evolve ever quicker and the boundaries between disciplines become blurred in certain areas of academic and scientific specialisation (Lam 2000). Nor do they any longer provide an absolutely sound basis for matching supply to demand in certain R&D activities. As a result, an alternative mode of adjustment is emerging at the interface between the academic and industrial spaces; networks make it possible not only to identify, contact and sift the talents that best match specific needs but also, and above all, to co-produce them through university/industry collaboration. The recruitment of PhDs depends to a fairly large extent on these types of mechanisms. However, these mechanisms, which are intended to reduce uncertainty or to bring the two spaces closer together, are deployed within a set of national institutional arrangements. In consequence, they are regulated differently and have

meanings that differ considerably from country to country, particularly as far as the recruitment of PhDs is concerned.

a) In the **United States**, the university system can be said to have integrated itself into its economic environment by adopting the principles that animate the business world, that is the provision of commercial services in the marketplace. Thus American universities position themselves in the same competitive arena as firms in order to satisfy their funding requirements. This inter-institutional competition and the provision, on a commercial footing, of various services based on the academic and scientific knowledge at their disposal have helped to legitimate the notion of the 'entrepreneurial university', a symbol of institutional innovation that dates back to the founding of the Massachusetts Institute of Technology. This type of strategic behaviour, duly legitimated and consistent with the American university ethic, enables universities to trade in patents or to establish, on a large scale, high-tech companies as spin-offs from their research activities. It is this general context that shapes the use and flows of doctoral students and PhDs.

According to an NSF survey (S&E Indicators 2000, NSF), slightly fewer than two thirds of PhDs are employed in academic jobs three years after obtaining their doctorates, while one quarter are employed in business and industry. Apart from the scale of the academic market, this survey reveals two phenomena.

Firstly, the PhD recruitment rate in industry shows an upward trend over time, although it fluctuates with the business cycle and, even more so, from subject to subject. The share of PhDs in engineering entering industry is greater than that of PhDs in science: 57% of those with doctorates in engineering were working in the private sector in 1997, compared with 40% for computer science and 20% for the life sciences.

Secondly, the share of young scientists in intermediate positions at the intersection between academia and industry is growing fairly rapidly. This increase, due largely to the establishment of post-doc positions, reflects a strengthening of the competitive selection mechanism governing entry to the academic market and the increasingly precarious nature of their situation as a result of being employed on a succession of short-term contracts. This phenomenon is most apparent in the life sciences, one of the areas in which American science excels. For example, 60% of new PhDs in this area find themselves in such intermediate positions, and they account for half of all post-docs (5,600 out of 10,700) in the USA. In areas such as this, young high-level scientists employed on extremely flexible contracts alternate between research programmes, temporary posts in industry and academia or even the start-ups established by university teaching staff while they wait to settle down in permanent positions¹³: individual mobility of this kind is mediated essentially through reputation, established by formatting knowledge in the form of academic publications, or through socio-professional networks. Fluidity of this

¹³ However, this fluidity on the part of candidates does have its downsides: there is a risk that talents will be exhausted and academic careers made to seem less attractive.

kind creates a labour market that is often embedded in a local academic community (Palo Alto, Biotech-Bay in California, Boston etc.) gravitating around a core of university institutions and academic spin-offs that functions as an 'intermediate space' in which scientific knowledge is disseminated. Combined with the influx of foreign post-docs seeking to familiarise themselves with the latest developments in biotechnology, it also influences the trend towards the externalisation of R&D activities by pharmaceutical companies and the constitution of an international space within which certain 'hybrid' actors move, transcending the long-established national and professional boundaries of the university, the industrial researcher or the entrepreneur.

b) In the **United Kingdom**, there is a tradition of autonomous universities able to manage, at local level, their own relations with the political and administrative authorities as well as with firms. The universities' ability to take advantage of their autonomy in order to establish and sustain local links explains the existence of clusters of innovative companies around certain universities, most notably Oxford and Cambridge. At the same time, the free-market policies of successive governments and its corollary – the reduction of public funding for teaching and research – have further encouraged universities to develop their activities in this area.

Against this background, an increasingly high share of doctoral students is being supported by joint industry/university programmes, such as the CASE and PTP programmes (see footnote 4). A comparative study of France and Great Britain (Mason 2000) also found that doctoral students in Great Britain seem to be significantly more involved than their French counterparts in industrial projects, particularly in SMEs in the electronics and biotechnology industries. Apart from the fact that many multinationals have established laboratories in the vicinity of certain universities, which in itself creates a strong demand for scientists, British firms are more likely to recruit PhDs to work in their R&D departments than French firms, which display a marked preference for 'engineers' trained in the *grandes écoles*. Consequently, a good number of doctoral students look to industry for employment once they have completed their theses. According to the OST, one third of the doctoral students funded by the Research Councils find jobs in the private sector on completion of their PhDs. Whereas it is becoming increasingly difficult to find stable employment in academia, because of cuts in university funding, the increase in contract research and the drastic reduction in publicly funded research laboratories, industry is seeking to co-produce and reclaim a certain proportion of PhDs by forging strategic partnerships with universities. Similarly, a certain degree of disintegration in the publicly funded research sector and the presence of a significant pool of contract research staff in the universities have helped to create a specific category of 'hybrid' actors made up of professionals and academics who have become self-employed in order to provide services to firms or to act as sources of high-level skills that can be called on for specific scientific/industrial projects. The presence of this category of actors makes the British R&D system extremely flexible.

In order to regulate the links between the HERS and firms, the two continental European countries make less use of 'market intermediation' than the USA, where scientific reputation can be as financially profitable in academia as it is in industry, or the UK, where the porous boundaries between the public and private spheres have created an enormous area of great flexibility. In their different ways, Germany and France have each structured a space in which industry/academia collaboration takes place, the nature of which influences the ways in which PhDs enter the labour market.

c) In **Germany**, close links between academic research and industry have existed for a long time, both in large firms and in SMEs. There are many research centres jointly funded by the state and firms in which university and private-sector researchers work together with a view to developing products up to the pre-competitive stage (the Fraunhofer Gesellschaft, for example). In addition to the long-established practice of firms providing periods of training in the workplace for university students, German industry frequently calls on university professors and doctoral students in a process of 'cross-fertilisation' that is regarded as the key to its success, particularly in the chemical and pharmaceutical industries. Moreover, these links seem to be forged at local level, since the universities and research institutes, most of which are administered by the *Länder*, are deconcentrated, which encourages the diffusion of academic research within the local industrial fabric.

These close links between industry and academia based on local networks are constructed around a professoriate whose individual members enjoy considerable personal autonomy in managing science/industry relations. This has a direct influence on the integration of German doctoral students into the labour market. Thus PhD students and post-docs are very often involved in the collaborative projects that university professors manage on behalf of firms. Industrial contracts, and the funds they bring in, are an integral part of PhD programmes. Professors are in effect part of the corporate management hierarchy and are responsible for supervising young researchers in both the industrial and academic aspects of their work. Furthermore, post-docs are sometimes strongly encouraged by their professors or other academic associates to launch spin-offs on the basis of their joint research. This type of 'patronage' seems to reduce the probability of young PhDs finding themselves in precarious employment situations in the early stages of their careers.

From a statistical point of view, Enders (2001) shows that one year after obtaining their doctorates, only 60% of PhDs in biology and mathematics stay in the public sector, mainly in the universities. On the other hand, 60% of PhDs in electronic engineering and almost one third in biology are employed in the private sector. Thus the career paths of German PhDs seem to be more diversified than elsewhere.

Whatever their discipline, German PhDs seem to be much less reluctant than their counterparts in other countries to seek careers in industry¹⁴, firstly

¹⁴ And also, in a negative sense, because the trajectories of young academics are lengthy, tortuous and dependent on their professors until they themselves obtain a tenured position.

because of the cognitive proximity between the academic and industrial spaces and, secondly, because of the high status of researchers in industry, which opens up very good promotion prospects.

d) Despite a higher education and research system that is characterised both by state centralism and a certain degree of inwardness – expect in the prestigious engineering schools (*grandes écoles d'ingénieurs*), which have always maintained close links with industry – **France** has developed forms of collaboration between academia and industry that have sometimes proved to be very efficient in the past. Governments have frequently initiated sectoral action programmes (such as the Plan Calcul, which was meant to ensure French strategic independence in computers, Plan Télécom etc.) and, adopting a mission-orientated approach to policy, have also provided the impetus for large-scale technological programmes. In doing so, they looked for support to numerous scientific and technological research organisations as well as to the large national firms, both private and publicly owned, that were the leaders in their sectors. These latter were involved in the large-scale technological programmes more as 'purchasers' than as the initiators of scientific collaboration. Thus technological diffusion was conceived in a centralised, top-down way, with companies being little involved in defining objectives. However, this organisational structure, which prevailed until the early 1990s, has begun to change, with greater decentralisation helping to break down the boundaries between the public and private spheres. Thus the French system is evolving in two directions. On the one hand, reduced centralism is giving technological support programmes a more regional character and is leading to the development of local networks involving universities, research laboratories and SMEs. On the other hand, there is increasing financial autonomy within the HERS and the financial flows from firms to academia are increasing.

That said, relations between the HERS and French companies are still deeply influenced by the weight of the past in that they remain highly formalised and structured. Thus some large companies continue to maintain long-standing, privileged relations with certain public laboratories or universities; these relations may take the form of jointly operated laboratories, so-called 'economic interest groupings', or partnerships, or research agreements. These forms of links involve mutual, long-term commitment, exclusive 'one-to-one' relations and formalised transactions.

It is within this framework of science/industry relations that PhDs in France are deployed and integrated into the labour market. According to one study (Cereq 1999), slightly fewer than two thirds of them are employed in the public sector (higher education and public research institutions) three years after obtaining their doctorates, while one third are employed in the private sector. Thus the academic labour market, which operates in accordance with the rules laid down for the civil service, remains the main source of employment for PhDs. The differentiation between public and private career paths emerges at a fairly early stage, therefore, with each 'space' creating its own relatively impervious segment within the internal labour market. This differentiation is even present at the time when funds are allocated to

prospective PhD students¹⁵. Those in receipt of public funding tend to seek employment in the academic labour market, while those supported by industry or the CIFRE programme are very likely to seek employment in industry, possibly even in the companies that have been funding their studies¹⁶.

In this latter case, both the allocation of industrial contracts (or grants) and the labour market integration of those being supported in this way depend on the networks that university or other public research laboratories have established with certain companies. It is the recurrent nature of these relations that encourages the establishment of these networks between the partners. Doctoral students play a central role in maintaining these networks, since they become integrated into them by virtue of the reputation of the institution to which they are affiliated and at the same time function as a key link in their reproduction.

The use of doctoral students in university/industry collaboration in France is further characterised by two considerations of an economic nature. For both partners, it is one of the least costly and least risky ways of organising such collaboration; a PhD thesis that takes 3 to 4 years on average to complete can serve as an exploratory study of emerging areas or topics. This type of technological wager gives firms a certain degree of flexibility: they can decide whether or not to internalise the co-produced knowledge or competences depending on the potential revealed by the doctoral student's findings.

e) In **Japan**, only a small minority of young PhDs find employment in the private sector; the vast majority enter the academic labour market. Considered to be inflexible when it comes to the selection of research topics, PhDs are not held in high regard by Japanese companies, which prefer young scientists with master's degrees requiring six years of higher education for their R&D function. As in Germany, it is the professors and the networks they have established that play the pivotal role in matching demand from firms to the supply of new graduates, including PhDs.

Despite the lack of opportunities for young scientists in industry, it should be noted that an increasing number of engineers making their careers in the private sector are submitting their theses to universities after acquiring a certain amount of professional experience. Half of the 3000 theses submitted annually in engineering fall into this category. This would suggest that a new category of 'researcher/PhD' might be emerging within firms, one that is clearly distinct from the R&D engineer category. With a greater affinity with the academic space, this category might provide the first 'hybrid' actors capable of transcending the boundaries between academia and industry.

¹⁵ In addition, there are the engineers graduating from the *grandes écoles* with PhDs who have a dual competence as researchers and engineers that enables them to operate within both the academic and industrial spaces. In itself, the status of researcher has no legitimacy in French industry, unlike in Germany. However, it is the status of graduate engineer that really marks out the elite and opens up prospects of promotion through the management hierarchy.

¹⁶ In the case of the CIFRE programme, participants in which are jointly funded by industry and the state, 78% of new PhDs enter the private sector, with 54% remaining with the partner companies (ABG Formation 2001).

Conclusion

The hybridisation of science and technology is creating a new intermediation space between academia and industry. The creation of this new space has been accompanied by the emergence of new structures, such as academic start-ups, university incubators, technology licensing offices (TLOs), research consortiums etc., whose purpose is to facilitate the interactive circulation of knowledge between the academic and industrial spaces. The emergence of the 'intermediate' labour market as a mechanism for the co-production and transfer of competences is an important element of this general phenomenon.

In all the countries investigated, this hybridisation gives rise to a dual trend that is sometimes contradictory, sometimes complementary. On the one hand, there is undeniably a trend towards convergence between countries. The scientific world is 'globalised', and indeed has been for a long time, since the system of competition and scientific reputation is now being built up in the international arena, at least at the top level. Consequently, all the outputs of scientific activity (articles, patents, PhDs etc.) tend to be evaluated relative to a few 'universal' criteria of excellence. This in turn sets in motion similar trends in all countries. Thus systems for producing new PhDs programmes are converging markedly towards the American graduate school model – or at least towards various interpretations of that system – which is, as it were, acquiring universal legitimacy. Similarly, the increase in scientific projects involving international teams (research consortiums, joint publication of articles etc.) is having the effect of standardising research practices and researchers' professional rules. Finally, the globalisation of multinationals' R&D functions serves to reinforce this trend further by standardising HRM norms for researchers beyond national boundaries.

On the other hand, while this form of competition based on global reputation is leading to the emergence of centres of excellence, many of them in America, and at the same time causing scientists and students to migrate towards them, it is not completely eliminating the specificities of the national institutions involved in the production of scientific output.

In fact, more detailed observation shows that this convergence towards the American model, whether assumed or desired, has met with a variety of responses in the different national contexts. As our analysis suggests, the market for PhDs functions in different ways depending on the particular institutional arrangements associated with the various industrial sectors and disciplines or with national policies on the higher education and research system. Higher education and research institutions, which in all the countries are the heirs to a considerable national heritage are in fact shaping the basic architecture on which the arrangements, rules and practices governing university/industry relations are based. In this sense, the 'intermediate' labour

market and the innovation space are 'social constructs' that are deeply embedded in an overall societal context¹⁷ (Maurice, Sellier, Silvestre 1986).

Thus the coordination mechanisms, such as signalling, reputation, networks etc., that regulate the labour market for scientists have to be interpreted in the light of this societal context. Regulatory mechanisms may bear the same designations, but their significance often differs, depending on the space in which they function.

This is true of the notion of 'network', which plays an essential role in the intermediate labour market. Far from being homogeneous or polymorphic, it has a multiplicity of meanings and a variety of functions depending on whether it is part of a local community context in California, of a German or Japanese context characterised by personalised relations based on the status of professor or in a French context in which relations between the various entities are quasi-institutionalised. Although the networks in which scientific knowledge and competences are produced transcend, in theory, the various boundaries and are transnational in nature, they are also fragmented or differentiated by the construction of human and social realities, in particular societal reality (see the recap figure).

Over and above this general conclusion, which bears out some of the arguments advanced by the national innovation system schools (Lundvall 1992, Edquist 1997) and the varieties of capitalism approach (Hall and Soskice 2000), particularly in terms of institutional advantages, two policy implications can be briefly outlined.

- The policy of establishing a limited number of centres of scientific excellence along the lines of the American university model, which has been pursued almost everywhere for some time, creates certain tensions in Western European countries and in Japan. It tends to produce a Matthews effect (a self-reinforcing mechanism in a situation of informational asymmetry), which encourages the emergence of a small group of renowned establishments and a separation between research universities and training universities, with the latter concentrating almost exclusively on teaching at the expense of research. Apart from the fact that segmentation of this kind between research and teaching is not desirable from the point of view of educational effectiveness, there is a risk that this trend will not only reduce the diversity of research, in terms of both form (applied, basic, etc.) and approach (theoretical, normative, experimental, etc.), but also restrict the range of possible research topics. Moreover, it strengthens the position of standard theories as the dominant academic and scientific paradigms and often leads to the homogenisation of PhD quality norms. This competitive model particularly disadvantages many regional universities of average size that meet specific local needs. Consequently, science and higher education policy, whether national or European, should take greater account of the need for variety in research and use public research funds to support a certain degree

¹⁷ This general construction process can obviously take different forms depending on whether it takes place at the sectoral, local or supranational level. Further studies will highlight the variety of forms at sectoral and local level.

of institutional diversity, which remains the best way of guaranteeing creativity in the long term.

- The training-job transition of new PhD recipients is becoming increasingly difficult and uncertain everywhere, because there is a structural shortage of the academic jobs for which they are primarily being trained. As the use of post-doctoral research positions is increasing and being extended, precarity among young researchers is increasing well beyond any 'reasonable' limit. A certain degree of precarity at the beginning of academic careers – associated with the well-known phenomenon of the labour queue – seems to be inherent in the nature of scientific and academic research, in that time is needed for the selection process in a situation of uncertain quality. As we have seen, this precarity was traditionally managed by the various forms of relationships between actors and organisations in the networks that operate - in different ways from country to country - in the intermediate space. Nevertheless, the rapid development of the systematic use of post-doc positions, which are regarded in part as a source of cheap labour, is tending to unbalance or even disrupt the intermediate labour market. The public authorities have an important role to play in bringing this market segment back under control through the use of various regulatory or incentive mechanisms. Without a voluntarist intervention, which should certainly be adapted to each country's circumstances, the pool of young researchers may well dry up, either through depletion or because young people are discouraged from entering academia. In the long term, this would undermine the very basis of knowledge production.

Annex: Typology of PhD student socialisation models

Country	USA	Japan	France	Germany	UK
Funding of doctoral programmes	Multiple (grants, fellowship, job), but importance of direct employment cost in the form de research contracts (research or teaching assistants : 65-75 %) : (Source NSF)	Mainly bank loan without interest, few grants and fellowship	National grant MNRT (30-50%) + Research contracts In total 75-95% of PhD are financially assisted (Source MNERT)	Federal research/teaching contracts or research grant (70-90% as junior university staff - full or part-time) + diverse fellowship	Grants from Research councils or publics Funds (75 % of full-time students). Attribution based on individual merit, Auto-financing for 20% of full-time and 50% de part-time students
Characteristics of doctoral student	Heterogeneous population, Lot of foreign students (40-60%) (Source: SEI-NSF appendix table 2-33)	Young PhD or lot of thesis on works presented by salaried engineers (50% in engineering). less foreign students (20 %)	Young PhD (- 30 years old) + less foreign students (20-25 %)	Students graduate later (33-year old in engineering, 31,5 in science). Less foreign students (8 - 15 % en 1996)	Heterogeneous population: Very young PhD, part-timers and more foreign students (30-50%) (Source : SEI-NSF appendix table 2-33)
Implicit contract between student and director	Contract based on individual scientific merit	Personalised Contract (Master - disciple relationship)	Institutional Contract (laboratory - candidate)	Personalised Contract (Master - disciple relationship)	Contract based on individual scientific merit
PhD Training-career transition	Dual orientation (75% in universities or IRP and 25 % in industry, 3 years after the graduation) and progressive transfer towards industry	Dominant academic orientation = more than 80%	Dual (academia/industry) orientation (50-70 % academia against 20-30% industry, 3 years after), Cifre granted students 75% in industry	Diversified orientation (30-60% public sector [HE+IRP]) against 30-60 % in industry, 1 year after)	Dual orientation (welcome foundation survey ; 80% for first job and 60% 3 years after in academia), Case granted students for industry
Academic labour market	«Tenure » effects, competitive selection of scientists + precarious situation and mobility of young PhD, Labour market segmentation training/ research universities	Early occupational stabilisation of young PhD, Internal promotion, Segmentation Univ./lab public and private	Early occupational stabilisation of young PhD (civil servant status), Internal promotion, Segmentation public and private research	Division between professors with « habilitation » and non-full term assistants, long selection process + precarious situation of young scientists	« Tenure » effects in spite of its formal suppression. Precarious situation and long selection process of young scientists, Segmentation polytech- Univ./ traditional Univ.
PhD status in Industry	Average, but combined status of professor/entrepreneur highly esteemed	Weak and hardly distinctive from other educational titles	Relatively non-distinctive, competed by title of graduated engineer 'ingénieur diplômé'	High status of PhD, possibility of career promotion	Average, status of scientific expert esteemed
Career path	Inter-establishment mobility in academia and transversal mobility between academia and industry are high (Career mix)	Weak mobility (industrial/academic careers in separation)	Weak mobility (industrial/academic careers in separation)	Relatively high mobility in the first part of career (diversified careers)	Relatively high mobility in the first part of career (diversified careers)
Type of model	Reputation-based competition model (quasi market model)	Relational (professoriate) model	Institutional hierarchy model	Professoriate centred model	Professional model

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